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EXPERIMENTAL STUDIES ON PARTIAL REPLACEMENT OF NATURAL SAND WITH MANUFACTURED SAND

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ABSTRACT

Natural or River sand are weathered particles from rocks which are of various shapes and sizes depending upon the weathering action of rivers. In the present scenario, natural sand with required properties is not easily/locally available. In most of the situations, the natural sand is being brought from faraway places to the construction site. Such type of transporting the river sand from faraway places will increase the construction costs. Also these natural river sand is also becoming unavailable due to many reasons. Hence it is very essential to find an alternate material that can substitute the natural river sand either partially or fully. In Tamil Nadu, stone quarries are found in abundance and are wide spread across the state. They are the good source for the coarse aggregate and manufactured fine aggregate. There is a need to make use of the stockpiles of quarry fines generated in those crushers. Hence to make use of these M-sand in the construction industry, a systematic study has to be carried out on the replacement with Natural River sand in making concrete. Experimental investigations carried out on the evaluation of properties of M-sand obtained from different locations (sources) is presented in this paper. Based on the experimental results, mix design for different grades of concrete was carried out using M-sand obtained from two sources by replacement of natural sand. Experimental studies carried out on the properties of fresh and hardened concrete made using the developed mix proportions is also presented in this paper.

Keywords: Manufactured Sand, Concrete, Fresh Concrete, Hardened Concrete, River Sand Replacement

1.0 INTRODUCTION

In the recent years, the Indian construction and infrastructure industry has seen rapid development. The main natural raw material used by the construction industry is natural river sand as fine aggregate in concrete. Construction diligence with sustainability is of great importance.Sustainability is a broad term describing a desire to carry out activities without depleting resources without compromising the ability of future generations to meet their own needs. The term sustainable development can be described as enhancing quality of life and to improve social, economic and environmental conditions for present and future generations.Natural or River sand are weathered particles from rocks which are of various shapesand sizes depending upon the weathering action of rivers. In the present scenario, natural sand with required properties is not easily/locally available. In most of the situations, the natural sand is being brought from faraway places to the construction site. Such type of transporting the river sand from faraway places will increase the construction costs. Also these natural river sand is also becoming unavailable due to many reasons. Hence it is very essential to find an alternate material that can substitute the natural river sand either partially or fully. The new material should also have the similar properties of that of the natural river sand. Hence the research around the world is focusing towards the usage of manufactured sand as partial/full replacement for river sand. Manufactured sand (M-sand) best substitute for river sand for construction activities. This M-sand is obtained during the crushing of hard granite stone. The M-sand is of cubical shape with grounded edges, washed and graded to as a construction material. The M-Sand usually consists of particles from 150 microns to 4.75 mm in suitable proportions. The proportion of finer particles in the M-sand should be more so that the percentage of voids will be lesser. Thereby the quantity of cement required for the construction activities will be reduced. Hence by using such types of M-sand will make construction economical without depleting the natural resources. Hence demand for using the M-sand for making concrete is increasing day by day as river sand cannot meet the rising demand of construction sector. The formation of natural river sand is very slow process and takes several years. Because of the limited supply, the cost of river sand is very high and regular supply is also not available. Under these circumstances use of M-sand becomes essential. Also the silt content and organic materials in the river sand is high compared with that of the M-sand which affects the durability and life of concrete structures.

M-sand is acquired in required grading to be used for construction purposes as a replacement for river sand, produced from crushing of granite stones. The sizes of M-sand can be controlled easily so that it meets the required grading for the given construction is an added advantage or otherwise the M-sand is defined as a purpose-made fine aggregate produced from quarry fines of certain types of rock through further screening and processing. Some of the general requirements of M-sand are: it should have particles with higher crushing strength, smooth surface texture and without organic impurities. Suchiitra et al. (2014) presented the studies carried out on partial replacement fine aggregate in self compacting concreteand compared performance of the various percentages of replacement. Elavenil & Vijaya (2013) carried out studies on workability and compressive strength of concrete mixes made by replacing the river sand with M-sand. Experimental investigations on replacement of river sand with M-sand was carried out by Adams Joe et al. (2013). It was found that the inclusion of steel fibres and chemical admixtures increased the strength and workability. It was reported that 50% replacement of fine aggregate by M-sand gave better strength and durability aspects than the conventional concrete. From the reported literature it can be seen that quarry fines are more suitable for replacement of natural river sand. In Tamil Nadu, stone quarries are found in abundance and are wide spread across the state. They are the good source for the coarse aggregate and manufactured fine aggregate. There is a need to make use of the stockpiles of quarry fines generated in those crushers. Hence to make use of these M-sand in the construction industry, a systematic study

has to be carried out on the replacement with Natural River sand in making concrete. The raw material for M-sand production is the parent mass of rock. It is based on the parent rock that the chemical, mineral properties, texture and the composition of sand would change. Experimental investigations carried out on the evaluation of properties of M-sand obtained from different locations (sources) is presented in this paper. Based on the experimental results, mix design for different grades of concrete was carried out using M-sand obtained from two sources by replacement of natural sand. Experimental studies carried out on the properties of fresh and hardened concrete made using the developed mix proportions is also presented in this paper.

2.0 EXPERIMENTAL STUDIES ON EVALUATIN OF MATERIAL PROERTIES OF M-SAND

Prior to the experimental investigations M-sand samples were collected from different localities like Thanjavur, Thirunindravur, Sriperumbdur, Keeraipakkam, Theriveni and Erode. Sieve analysis, Specific gravity tests, density tests, microscopic analysis and Blain's apparatus test were carried out on the collected samples to determine the suitability for using as replacement for river sand.

2.1 Sieve Analysis

The M-Sand obtained from different sources was taken for the sieve analysis (Fig. 1).After shaking the material through the nested sieves, the material retained on each of the sieves of size 4.75mm, 2.36mm, 1.18mm, 600 micron, 300 micron and 150 micron is weighed. The percentages of M-sand passing through various sieves are plotted as shown in Fig. 2.

Fig.1 Sieve Analysis and Typical Samples Obtained

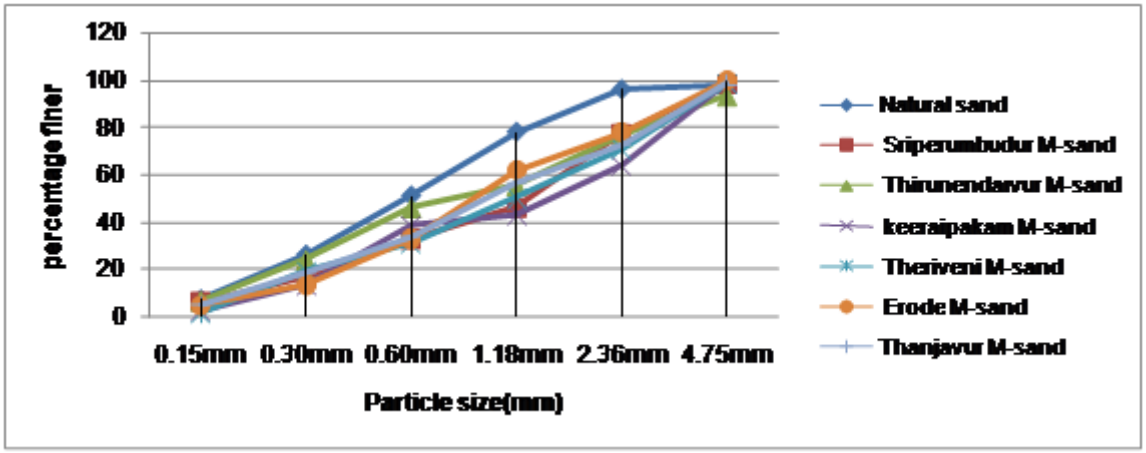

Fig.2 Particle size distribution of collected M-sand samplesand natural sand

2.2 Specific Gravity

The specific gravity of the collected M-sand samples was determined. The mass of fine aggregate sample is determined in saturated surface dry, oven-dry and submerged states. These values are then used to calculate the specific gravity and the evaluated values are given in Table1.

Table 1 Specific Gravity of Collected M-sand samples

M-sand Sample	SPECIFIC GRAVITY
Keeraipakam	2.6
Theriveni	2.64
Erode	2.6863
Thanjavur	2.65
Sriperambadur	2.76
Thirunendravur	2.8

2.3 Density and Loose Density

The bulk density and loose density of the collected M-sand samples was determined by adopting standard procedures. The evaluated density for the collected samples is given in Table2. From the table it can be seen that the percentage of voids is less in most of the samples.

Table 2 Density of Collected M-sand Samples

M-SAND SAMPLES	BULK DENSITY	LOOSE DENSITY
Keeraipakam	1.67	1.63
Theriveni	1.64	1.65
Erode	1.614	1.902
Thanjavur	1.626	1.826
Sriperambadur	1.692	1.79
Thirunendravur	1.728	1.56

2.4 Microscopic Analysis (ASTM C 457 AND C 856)

The shape and texture of fine aggregate have an important effect on workability of fresh concrete and have an effect on strength and durability of hardened concrete. The effects of shape and texture of fine aggregate are much more important than the effects of coarse aggregate which plays a vital role. The shape and surface texture of natural sand and M- sand were viewed by a high resolution microscope. The microscopic view of the natural sand and M- sand is shown in Figs.3 (a) and (b).The natural sand has rounded particles and smooth surface texture which may increase the workability of the concrete. The M- sand particles are angular in shape and have rough surface texture, which may improve the bond between the particles.

(a)Natural sand **(b) M- sand**

Fig.3 Microscopic view of Natural Sand and M-sand

2.5 *Blain's Apparatus Test*

The particle size of M-sand in terms of their specific surface area was determined using blain's apparatus test. It consists of a stainless steel cell, perforated disc and plunger. M- Sand samples of weight 2.8g is taken for conducting the test. The value of specific surface area of the samples of M-sand collected is given in Table 3. The Finer M-sand offers a greater surface area for hydration and hence faster the development of strength.

Table 3 Blaine's value of collected M- sand samples

M -sand sample	Blaine's value (Average value)
Sriperumbudur	912.6 cm^2/kg
Thiruninravur	969.7 cm^2/kg
Erode	747.8cm^2/kg
Keeraipakkam	821.9cm^2/kg
Theriveni	701.1cm^2/kg

Experimental studies were carried out on physical and micro structural properties of M- sand. From the experimental investigations, it is observed that the M- sand can be used for partial replacement of natural river sand. Further studies were carried out using samples obtained from Sriperumbudur and Thiruninravur due to their better suitability and availability for concrete.

3.0 MIX DESIGN BY PARTIAL REPLACEMENT OF RIVER SAND USING M-SAND

Mix design was carried out using IS 10262-2009 for M25, M30 and M40 grades of concrete. In the design mix, natural river sand was partially replaced by 50% and 70% with M-sand. Crushed angular aggregate with sizes of 12.5mm and 20mm confirming to IS: 383-1970 was used and having bulk density of 1728 kg/m^3& loose density of 1527 kg/m^3. The coarse aggregate was tested with reference to IS: 2386 -1963.The specific gravity was found to be 2.80 for 20mm aggregate and 2.68 for 12.5 mm aggregate and fineness modulus is 2.75. Water absorption of coarse aggregates with reference to IS: 2386 (Part III)-1963 was determined as 20.6%. The impact test was performed to determine the toughness of the aggregate sample and the impact value obtained was46.5%. The crushing test was carried out to find the compressive strength of the aggregate and found to be 30.3%. Locally available river sand having bulk density of 1860 kg/m^3 and specific gravity of 2.56 was used. The Fineness modulus of river sand is 2.64.Ordinary Portland Cement of 53 grade confirming to IS 12269-2013 was used in the experimental investigation. Laboratory tests were conducted on cement to determine standard consistency, initial setting time, final setting time and fineness modulus as given in Table 4.

Table 4 Properties of Cement

Particulars	Values
Grade	OPC 53 Grade
Specific gravity	3.15
Fineness	7%
Initial setting time	85 minutes
Final setting time	345 minutes
Standard consistency	28%

Mix proportions for M 25, M 30 and M 40 grade concrete were arrived at for the natural sand with different replacement levels of M-sand and given in Tables 5 to 7. The specific gravity and fineness modulus values of each replacement level of M-sand were considered.

Table 5 M 40 Mix

SAMPLE	%	Cement	Fine Aggregate		Coarse Aggregate		Water
			M SAND	N SAND	20mm	12.5mm	
	0	410	0	798.7	694.2	462.8	184.57
Sriperumbudur	70	410	476.79	239.61	694.2	462.8	184.57
	50	410	340.57	399.35	694.2	462.8	184.57
Thiruninravur	70	410	512.9	239.61	694.2	462.8	184.57
	50	410	366.39	399.35	694.2	462.8	184.57

Table 6 M 30 Mix

SAMPLE	%	Cement kg/m^3	Fine Aggregate		Coarse Aggregate kg/m^3		Water l/m^3
			M SAND kg/m^3	N SAND kg/m^3	20mm	12.5mm	
	0	400	0	798.7	744.05	474.7	180
Sriperumbudur	70	400	489.11	245.8	744.05	474.7	180
	50	400	349.36	409.6	744.05	474.7	180
Thiruninravur	70	400	526.2	245.8	744.05	474.7	180
	50	400	375.85	409.6	744.05	474.7	180

Table 7 M 25 Mix

SAMPLE	%	Cement kg/m^3	Fine Aggregate		Coarse Aggregate kg/m^3		Water l/m^3
			M SAND kg/m^3	N SAND kg/m^3	20mm	12.5mm	
	0	390	0	664. 46	742.46	473.7	175.5
Sriperumbudur	70	390	499.6	199.3	742.46	473.7	175.5
	50	390	356.8	332.2	742.46	473.7	175.5
Thiruninravur	70	390	525.07	199.3	742.46	473.7	175.5
	50	390	375.05	332.2	742.46	473.7	175.5

4.0 FRESH AND HARDENED PROPERTIES OF CONCRETE WITH PARTIALLY REPLACED M-SAND

Experimental investigations were made on the evaluation of properties of fresh concrete like workability and on hardened concrete such as compressive strength and splitting tensile strength. All the materials were taken as per the mix proportion and for each percentage replacement and design mix properties of fresh concrete was evaluated. Then standard cubes and cylinders were cast for each design mix for evaluating the properties of hardened concrete.

4.1 Experimental Studies On Fresh Concrete

To measure the consistency of the fresh concrete workability plays a key role. Slump test is the most commonly used test method to measure the consistency of the concrete. Slump test was carried out to evaluate the workability of the M 25, M 30 and M 40 design mix of concrete with different proportions of M-sand varying from 0, 50% and 70% using the slump cone apparatus as per IS 1199 –1991 (Fig. 4).From the table, it can be seen that for all the three grades of concrete, the slump value got reduced by the increase in the replacement levels of M- sand. The shape and surface texture of M-sand have a significant effect on the workability of the mix.The round shape and smooth surface texture of natural sand reduces the inter particle friction in the fine aggregate component, so that the workability is high in natural sand. M- Sand is angular in shape and the rough surface texture improves the internal friction in the mix, which reduces the workability of the concrete.

Fig. 4 Slump Test on a Typical Concrete Mix

Table 6 Slump Values of Different Design Mixes

% Replacement	Sriperumbudur (mm)			Thiruninravur (mm)		
	M25	M30	M40	M25	M30	M40
0%	100	100	100	100	100	100
50%	84	80	85	89	77	87
70%	40	40	35	58	55	50

4.2 Experimental Studies On Hardened Concrete

Experimental investigations were carried out on standard concrete cubes and cylinders to evaluate the properties of hardened concrete. The compressive strength of concrete cube was as per IS: 516 - 2006. Ten cubes of size 150mm x 150mm x 150mm were tested for each trial mix combination after the age of 7 days and 28 days of curing using a compression testing machine (Fig. 5).From the table, it is observed that the compressive strengths are increased with the addition of M- sand for all the three grades of concrete. In the concrete mixes with Sriperumbdur M-sand there was an increase of 18% and 25% for 50% and 70% sand replacement respectively for 7 days whereas the increase in strength reduced to 13% and 22% for 28 days strength. In the concrete mixes with Thriuninravur M-sand there was an increase of 26% and 31% for 50% and 70% sand replacement respectively for 7 days whereas the increase in strength reduced to 24% and 26% for 28 days strength. This is due to the rough surface and angular particles of the M-sand, owing to the better interlocking between the aggregate and the hydrated cement paste. The rate of strength achievement is more at the early stages.

Fig. 5Concrete Cube Compression Testing

Table 7 Concrete Cube Compressive Strength in N/mm^2

M-sand Sample	Grade of Concrete	7 days compressive strength in kN/m^2			28 days compressive strength in kN/m^2		
		0%	50%	70%	0%	50%	70%
Sriperumbudur	M25	28.04	33.29	35.14	46.68	51.22	55.78
	M30	33.21	38.16	39.87	53.56	60.57	61.34
	M40	52.35	58.2	60.31	80.53	90.94	98.87
Thiruninravur	M25	28.04	35.47	36.77	46.68	58.15	58.37
	M30	33.21	39.11	42.04	53.56	63.08	64.68
	M40	52.35	59.46	61.95	80.53	92.91	101.56

Splitting tensile strength was determined in accordance with IS: 5816-2004 on cylindrical specimens of size 150mm diameter and 300mm height. The test was carried out by placing a cylindrical specimen horizontally between the loading surface of a compression testing machine and the load was applied until the failure of the cylinder. The splitting tensile strength evaluated for the concrete mixes is given in Table 8. There is an increase of about 25% in the splitting tensile strength of concrete when partially replaced with M-sand.

Table 8 Splitting Tensile Strength in N/mm^2 for Various Concrete Mixes

% replacement	Sriperumbur M-sand			Thiruninravur M-sand		
	M25	M30	M40	M 25	M30	M40
0%	3.11	3.29	3.47	3.05	3.16	3.40
50%	3.56	3.91	4.30	3.75	3.86	4.22
70%	3.90	3.98	4.00	3.80	4.00	4.10

The 0%, 50% and 70% replacement of river sand by M-sand provides greater strength to the concrete by reducing segregation, bleeding, honeycombing, voids and capillary. Thus the collected samples of M-sand makes the concrete, more compact and dense, thus increasing the strength of concrete.

5.0 CONCLUSIONS

From the experimental investigations carried out it can be seen that concrete with M-sand significantly improves the strength properties of the concrete. The rough texture and angular particles of M- sand create better interlocking between the particles. The slump value of the concrete mix with M-sand decreases than that of the conventional concrete. The properties of the hardened concrete is enhanced compared with that of the normal concrete. Hence from the experimental investigations, it is concluded that M- sand can be utilized as fine aggregate in concrete, which reduces the environmental impact, scarcity of natural sand and cost of construction. Even though the M- sand is already available in the market, there is a need to develop standards for usage of the M- sand.

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